Divided city, divided infrastructures:

Securing energy and water services in post-war Berlin

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Abstract

The division of Berlin's infrastructure systems following the blockade of 1948/49 posed an enormous challenge to the city's infrastructure planners on both sides of the political divide. This paper is a study of the destabilisation of apparently highly durable technical systems precipitated by the Berlin blockade and the subsequent efforts of those responsible to re-stabilise the systems. It investigates the different experiences of division in the electricity, gas, water and wastewater sectors with a view to raising our understanding of the durability and adaptability of urban technical networks in the face of major upheaval. In the immediate aftermath of the blockade, the paper argues, the prime concern of

network managers in both West and East Berlin was to maintain essential services in the face of interventions and reprisals from the other side. As prospects for re-unification diminished, the strategy shifted towards reducing the vulnerability and advancing the territorial cohesion of each side by re-ordering their technical networks physically, spatially and organisationally.

Keywords: *Berlin blockade, urban infrastructure, utility strategies, energy, water, vulnerability, resilience*

"These supply networks are like the internal organs of any living being. The life-supporting internal networks of an organism are protected, just like the underground infrastructure of a city. Any disturbance endangers the functioning of the whole. Substantial interference in these internal supply systems poses a threat to city life in general." (Prof. Ernst Randzio, in a speech to the Reconstruction Committee of the Berlin City Council, 16 May 1946)[1]

1. Introduction

On 24 June 1948 the Soviet military authorities in Berlin instructed the city's electricity utility Bewag, located in the Soviet sector, to cut off all power supplies to the three western sectors of the city. Deliveries of coal to power plants in the western part of the city were also to cease immediately. The following day the Soviet commandant dismissed Bewag's technical director, Wissell, for refusing to follow these orders and for holding a press conference to protest against the blockade of West Berlin. The western occupying powers retaliated by stopping the transport of coal from the Ruhr to the Soviet zone and cutting off all supplies of gas from West to East Berlin. The sudden truncation of flows of electricity and coal plunged West Berlin into a supply crisis far more severe than anything experienced during the wartime bombardment and invasion of the city. Without adequate electricity the sewage pumping stations in West Berlin were rendered temporarily inoperable, leaving the utility managers with no option but to empty sewage untreated into the city's watercourses, thereby creating a major public health hazard.[2]

The Berlin blockade and the proxy Cold War over Berlin's infrastructure systems pose an extreme, but also highly revealing, example of network disruption, the vulnerability of cities and the relationship between the two. We do not usually associate technical infrastructure

with disruption and volatility. Quite the reverse: "for most of us", Jane Summerton notes, "technical systems conjure up images of stability and permanence".[3] This paper is a study of the destabilisation of apparently highly durable technical systems precipitated by the Berlin blockade and the subsequent efforts of those responsible to re-stabilise the systems – organisationally, technically and spatially.[4] It investigates the experiences of division in the electricity, gas, water and wastewater sectors in both East and West Berlin with a view to raising our understanding of the resilience and adaptability of urban technical networks in the face of major upheaval. Here we follow Jane Summerton's exhortation:

> "By studying phases in which technical systems undergo radical change, we might expect to gain new insights into basic dynamics and properties of these systems."[5]

In the case of post-war Berlin interest lies in exploring what dimensions of the infrastructure systems changed – and what did not change – in the immediate and long-term aftermath of political division. Conceiving urban infrastuctures as socio-technical systems comprising a "seamless web" of technical, organisational and soci-economic artefacts,[6] we might anticipate different degrees of vulnerability, resilience and adaptability for each of these dimensions.

To guide our story we pursue two lines of investigation. The first set of questions relates to the coping strategies of infrastructure managers in crisis situations. What were the initial responses of those responsible to the physical, organisational and political division of Berlin's infrastructure networks? What longer-term strategies developed over time and how far were they directed at preserving the status quo or minimising dependence on the other side of the city? What do these responses tell us about notions of security and stability relating to large technical systems?

A second group of questions draws attention to the complex relationship between a city and its infrastructure in periods of political conflict.[7] In what ways did Berlin's infrastructure

systems become tools of political division during and after the blockade? Did they, at the same time, prove a source of strength and stability for the two half-cities? If infrastructure networks traditionally serve as "integrators of urban spaces"[8], what effect did their division have on the territorial cohesion of Berlin, both as a whole and on each side of the divide? Did the stabilisation of infrastructure systems in West and East ultimately jeopardise the future reunification of the city?

To provide answers to these questions the paper begins by describing the various manifestations of political division for each of Berlin's infrastructure systems (electricity, gas, water, wastewater), indicating how the dramatic events of the blockade affected flows of natural resources, people and information. The following section explores the responses of the infrastructure managers in West and East Berlin to the division of their socio-technical networks, distinguishing between emergency measures and longer-term coping strategies. These responses are subsequently interpreted in terms of the spatial re-ordering of the city's infrastructure systems and the consequences this had for future reunification. Finally, conclusions are drawn on what the case study reveals about the interdependence of a city and its infrastructure and about the resilience and adaptability of Berlin's urban technical networks in the face of long-term disruption.

2. Dividing the city, dividing the networks

2.1 The political division of Berlin

The building of the Berlin Wall in August 1961 – the most visible expression of the divided city – marked only the culmination point of a process of political division between the Soviet and Allied sectors of the city beginning in the late 1940s. Whereas flows of people and vehicles above ground were halted by the construction of the Wall, underground flows of

electricity, gas, water and wastewater had been truncated or severely restricted much earlier, during or after the blockade of West Berlin in 1948/49.[9]

The story of the Berlin blockade does not need to be repeated here.[10] For the purpose of our study we can summarise that the blockade was a calculated attempt by the Soviet Union to force the Western powers to sacrifice West Berlin, leaving political control of the whole city to the Soviet forces and its Eastern German allies. Failing this, the blockade would, at the very least, demonstrate the extreme dependence of West Berlin, located deep within the Soviet occupied zone, on the will and influence of the Soviet military authorities. The blockade entailed cutting off West Berlin's road and rail routes from Western Germany, as well as its electricity supply, without warning on 24 June 1948. The Western Allies were faced with the choice of either allowing West Berlin to starve and ultimately capitulate to Soviet pressure or attempting to supply this city of over 2 million inhabitants by air. The airlift between Western Germany and West Berlin, established immediately, became the only line of provision of essential goods for the beleaguered half-city until the blockade was lifted in May 1949, almost a year later. During this time some 213,000 flights delivered an astonishing 1.7 million tonnes of goods to West Berlin. Some two thirds of this tonnage came as coal used primarily for electricity and gas production.[11] The blockade disrupted not only flows of goods but also the fragile political unity of the occupied city. The Soviet authorities, once they had acknowledged the Western Allies' determination to support West Berlin, set about dividing the city politically. By the end of 1948 Berlin had two city governments – for the East and the West. West Berlin thus became an "island outpost"[12], isolated from its hinterland politically and economically, separated from the Allied zones in western Germany and deprived of its former functions as the capital of Germany. In the following section we examine how this process of political division manifested itself in the case of municipal services for electricity, gas, water and wastewater.

2.2 Disconnecting the networks

Electricity supply

Before the war electricity had been a far more important source of energy in Berlin than in any other German city,[13] earning the city the title as "perhaps the most famous 'electropolis' of all".[14] The city's power supply had been heavily dependent on the national grid, with the Berlin utility Bewag importing some 40% of its electricity in 1932.[15] Astonishingly, most of Berlin's own power plants survived the war.[16] Of the 750 megawatts generating capacity available in 1944, 391 megawatts remained at the end of the war and a further 63 megawatts were only temporarily unavailable owing to destroyed power lines and coal shortages.[17] Even during the height of hostilities, Berlin was without electricity for only 24 hours: on 27 April 1945.[18] Far more serious was the dismantling of power plants and removal of machinery by the Soviet military immediately after the war, conducted primarily in the western sector before the arrival of the Western Allies. The largest and most modern power plant in West Berlin – Kraftwerk West – was dismantled in its entirety. As a result, the generating capacity of the whole city was reduced by almost one half and of West Berlin by 90%.[19] At the time the blockade began, therefore, West Berlin had already experienced severe disruptions to its electricity supply and was extremely dependent on power supplied by the power stations in East Berlin and beyond. Not only the generating capacity, also most of the city's coal reserves were at the time stored at power plants in the eastern half of the city, notably at Klingenberg.[20]

When the supply of electricity and coal to West Berlin from the Soviet sector and zone was abruptly cut off in June 1948 it thus plunged the half-city into an unprecedented crisis. The airlift set up by the Western Allies was devoted primarily to supplying the coal needed to

keep the power stations in operation. In a desperate effort to restore West Berlin's generating capacity whole generators were flown in for the rapid reconstruction of Kraftwerk West.[21] To minimise the strain on the power plant, the military and civilian authorities in West Berlin imposed severe restrictions on the consumption of electricity and gas for all but the most essential tasks, with punishments for infringements ranging up to a 12-month prison sentence in the British sector. In an impassioned appeal to West Berliners Ernst Reuter, then city councillor responsible for utilities and transportation, graphically illustrated West Berlin's tenuous dependence on external energy sources:

> "Every kilowatt hour of electricity, every cubic metre of gas and every litre of water which is taken from our supply pipes costs coal. And new coal can only be provided by air."[22]

In the winter of 1948-9 West Berliners had on average only two hours of electricity during the day and two hours at night. Their per capita consumption fell as a result to a mere quarter of East Berlin levels.

Gas supply

In May 1945, following the wartime bombardment and the Soviet capture of Berlin, all eight of the city's gas works were out of action.[23] Of the 38 gas storage tanks, with a combined capacity of 2.1 million m^3, only one remained operational at the end of the war, with a volume of just 160,000 m^3.[24] For the first time in over 120 years the city was temporarily without public gas supplies. Strict rationing of gas was introduced by the occupying forces, with heavy fines for infringements.[25] Within two months, however, all but one of the gas works were operational and by the end of 1946 90% of the gas supply network and 50% of the production capacity had been restored.[26] The blockade of 1948/49 resulted in the complete separation of the gas supply networks in East and West, as with electricity. The decision to

cut off gas supplies was taken, however, by the Western Allied forces in retaliation for the Soviet authorities severing electricity supplies. This reflected the reversed dependencies in the gas sector. West Berlin possessed around 70% of the city's gas generation and storage capacity and was unwilling to continue supplying East Berlin with gas generated from coal which, during the blockade, had to be transported by air from Western Germany.[27] The physical disconnections of the gas supply networks involved shutting the valves on gas mains on or near the border. Where there were no valves the gas transfers in each direction were calculated and (after lengthy negotiations) billed to the other side.[28] By the end of 1950 the separation of the physical networks was complete: the service area of the West Berlin gas utility was henceforth almost wholly independent of the East.

Water supply

During the war Berlin's water supply system, despite bombing damage, remained fully functional up until the Soviet military advance into the city. Even during the worst of the fighting in April 1945 water supplies were disrupted only for a short period of time and in certain areas.[29] The immediate post-war concern was to secure sufficient coal supplies to operate the waterworks. As most water pumps were driven by diesel or steam West Berlin's water supply was not immediately affected by the power cuts marking the beginning of the blockade.[30] Nor were water services subject to the arbitrary or sudden cut-offs in supply experienced in the electricity and gas sectors – at least not during the initial months of the blockade. Prior to 1950 drinking water continued to flow freely between the two halves of the city. However, the dependence of areas close to the political boundaries on water from the other side became a source of conflict in subsequent years, as we shall see.

Wastewater disposal

In contrast to the water sector, Berlin's wastewater disposal system had been severely disrupted by the war. By 1945 aerial bombing had rendered all the city's sewage pumping stations inoperable, allowing raw sewage to flow untreated into bombed-out sites and open watercourses. The effect on public health was dramatic: in the later war years mortality rates from typhoid fever reached pre-1870 levels.[31] War damage had largely been repaired by the end of 1946, however. During and after the blockade the task of severing the sewer network was more difficult than with other underground infrastructures given the reliance on gravity and the diameter of the sewers. Blocking up sewers at border crossings would require re-routing wastewater along alternative networks. Since there were 97 cross-border sewers – 66 flowing from East to West Berlin, 31 flowing the other way[32] – this option was neither technically nor financially feasible. An additional physical deterrent to separating the networks lay in the radial structure of the sewer network. Wastewater was collected at central points in the city and pumped out to irrigation fields or sewage treatment plants (STPs) lying largely outside the city. For this reason around 90% of West Berlin's sewage was treated or disposed of on sites located in the surrounding Soviet zone.[33] As with electricity supplies, therefore, West Berlin's wastewater disposal system depended heavily on the will – and whim – of its political opponents.

2.3 Splitting the utilities

Parallel to the physical division of the infrastructure networks the Berlin blockade heralded the organisational separation of the utility companies in the two halves of the city. The division of the electricity utility Bewag began immediately after imposition of the blockade.[34] Between June and December 1948 a power struggle raged over control of the company and, in particular, of its headquarters located in the Soviet sector of the city. Interventions by the Soviet authorities to dismiss and replace senior company executives and to manipulate

representation on the Bewag workers' council were countered by reprisals from the West. Bitter accusations and counter-accusations between the two sides succeeded in splitting the workforce along political lines. When pro-western staff walked out of the company headquarters on 6 December in protest at the dismissal of the Bewag director Strassmann and the appointment of the pro-Soviet Witte the split of Bewag into two companies was complete. The experience of the other utilities was similar. Early in the blockade the Soviet authorities gave orders for the headquarters of the gas utility Gasag, also located in East Berlin, to be occupied and communications with the company's West Berlin offices to be disrupted.[35] On 26 March 1949 Gasag was split into two, at the same time as the water utility.[36] The wastewater utility had already been divided in late 1948. Henceforth each service was provided by a completely separate company with its own headquarters in the respective half of the city.

2.4 Disrupting knowledge flows

Other flows of vital importance to the functioning of the city's infrastructure systems were also cut off or redirected as a result of political division: flows of information, lines of communication and movements of people. During the struggles for control over the utility companies prior to their division, the military authorities on both sides attempted to prevent the movement of machinery, equipment and documents from plants or offices located in their own sector. The Soviet authorities, in particular, were concerned to stop staff sympathetic to West Berlin from smuggling important files, plans and maps from the head offices in East Berlin to the West. When the dramatic split of the utilities came, chief executives who vacated the central office buildings left only with what they could carry.

Since most documentary material was left behind in the East Berlin headquarters and staff from the West were denied access to it, the West Berlin utilities possessed wholly inadequate data about their own technical networks, hampering reconstruction work for years to come.[37] West Berlin's Gasag may have possessed 70% of the city's gas production and storage capacity but it had no plans or company records, no technical department, no store and no workshops.[38] Bewag-West technicians had to reconstruct from memory the layout of their part of the network of underground cables. The water utility in West Berlin lacked adequate documentation on the water supply network and data on water consumption. Consequently, the engineers had to draw up completely new plans from scratch – a painstaking exercise which took around a decade to complete.[39]

Some informal contacts were maintained across the political divide which helped fill some of the most urgent knowledge gaps on both sides. Such meetings between former colleagues were prohibited by the East Berlin utilities and had to be clandestine. These personal contacts tailed off, however, during the 1950s and were stopped almost entirely when the Wall was built. There remained subsequently only limited formal contacts between West and East, for example over contractual agreements for cross-border transfers or monthly meetings of senior technicians from the two power utilities.[40] The knowledge networks had been disrupted so severely that by 1968, according to Richard Merritt, "directors on both sides of the Brandenburg Gate learn about plans of the other side only through the press".[41]

The division of the utilities and their staff affected not only information flows but also the skills and knowledge of the respective workforces. The general tendency in 1949/50 was for the more highly qualified and better paid staff to follow the West Berlin utility and for a larger proportion of workers to remain with the East Berlin company. As a result Bewag-West had a surfeit of office staff and not enough workers and technicians, whilst Bewag-East suffered from the loss of key management personnel, as well as retaining only two fifths of the total

workforce. The damage of division to the workforce of the utilities well preceded the building of the Berlin Wall in 1961, in other words, when the flows of people were arrested completely.

3. Securing the systems

The political division of Berlin had, as we have seen, dramatic impacts on the territorial integrity, technical functionality and organisational structure of the city's infrastructure systems. This begs the question how those responsible responded to this immense and unique challenge. Looking beyond the immediate events of division surrounding the blockade – the era of de-stabilisation – we now turn to the efforts of the network managers (utility executives and infrastructure planners) to safeguard and stabilise their systems within the new geopolitical reality of a divided Berlin. How did they attempt to reorder their infrastructure systems and what notions of security guided their thinking when rebuilding the networks? It is useful to distinguish here between emergency measures taken to secure immediate supplies and longer-term strategies for infrastructure development.

3.1 Emergency measures

The immediate concern for network managers on both sides of the divide was to secure essential energy, water and sanitation services disrupted by the blockade and the post-blockade division of the networks. Attention focussed initially on arranging cross-border transfers in which energy, water and wastewater flows were allowed to pass from one side to the other at certain points in exchange for payments. Reaching agreement over the transfers invariably entailed protracted negotiations between the two sides. Until the flows could be

accurately measured there were frequent disputes over payments culminating in the more extreme cases in summary disconnections. Experiences of cross-border transfers differed significantly, however, between the various infrastructure sectors, meriting a closer look at the distinguishing features in each case.

Electricity: Following the end of the blockade on 12 May 1949 West Berlin was keen to reach agreement on the delivery of electricity from East Berlin, at least until the reconstruction of Kraftwerk West was complete. A contract was duly signed, on 18 July 1949, and over the next year Bewag-West received 457,000 Mwh, or ca. 56% of its gross output, from East Berlin and the Soviet zone.[42] Disputes over the renewal of this contract led to electricity supplies from East to West being summarily cut and restored as East Berlin exploited its powerful bargaining position to extract maximum concessions. A more stable arrangement was reached on 16 November 1950 involving a three-way agreement for Bewag-East to supply Bewag-West, the Hamburg power utility to supply Mecklenburg (situated in the Soviet zone) and Bewag-West to reimburse the Hamburg utility. The following months were relatively uneventful; indeed there were even cases of cross-border assistance following technical failures on both sides of the divide. In early 1952, however, the separation of West Berlin's electricity network took a further decisive step. On 4 March Bewag-East announced the impending termination of all electricity supplies to West Berlin, citing "disturbances in the East German power system". When offers of help from Bewag-West were ignored, the company had no alternative but to shut down the cross-border power lines. Richard Merritt describes the final act of separation:

> "Bewag-West did what it could. Its technicians took prompt action to recircuit Bewag-West's own electrical distribution, thereby forestalling a failure of the entire system of West Berlin. Until past two in the morning they cut, circuit by circuit, the lesser transmission lines of the grid that bound the two halves of the city together."[43]

Gas: Unlike the Bewag experience, contractual agreements between Gasag-West and Gasag-East were generally adhered to. This may be attributed to the much lower levels of dependency of Berlin as a whole on outside supplies and of West Berlin on supplies from East Berlin. Even before the war Berlin had not been served by long-distance gas mains, despite intensive wooing by the national Reichswerke.[44] Gas was produced from coal wholly at its own gas works. Nor was East Berlin in a particularly strong bargaining position, lacking adequate production capacity itself and – without access to Ruhr coal – dependent on coal from Upper Silesia that was less suitable for coking.

Water: As with electricity generation, the water supply situation was strongly asymmetrical in favour of East Berlin in the late 1940s. In terms of the water resources theoretically available to city waterworks East Berlin possessed twice the per capita capacity of West Berlin: 700,000 m^3 per day for 1.2 million inhabitants (East) compared with 600,000 m^3 per day for 2.1 million inhabitants (West).[45] Considerably more water flowed along water mains from East to West than in the other direction, tempting the East Berlin government to maximise compensation for the net water transfers to West Berlin. Protracted negotiations over the price of these transfers during 1949/50 ultimately broke down. Frustrated by the lack of progress, West Berlin officials disconnected all water mains linking the two halves of the city on 3 July 1950. This "precipitous action […] by Western officials"[46] had a far more detrimental impact on West Berlin than on the East, revealing the greater dependency of the former on cross-border water flows at this time. The borough of Neukölln, on the border with East Berlin, was cut off from its water supply for days, prompting the West Berlin authorities to lay emergency overland water pipes from the neighbouring borough of Tempelhof. After three weeks an agreement was reached over payment for water transfers and the mains valves were re-opened. Subsequent disputes over payments for water supplies led to less dramatic disconnections in April 1952 and again in 1957. The installation of water meters at border

crossings in 1953, permitting exact calculations of water transfers, helped reduce conflict between the two sides over this issue. In a memorable incident on 7 July 1953, just three weeks after the East Berlin uprising, officials from the West and East Berlin water utilities met on the Späth bridge between Neukölln and Treptow to successfully negotiate additional emergency water supplies for West Berlin following a particularly hot spell. Relations between the two were, from 1958 onwards, less prone to conflict as West Berlin gradually extended its own water supply capacity, reducing its dependency on the East (see below).

Wastewater: Following the organisational division of the Berlin wastewater utility, negotiations over payments for the transportation and treatment of sewage from West Berlin in the East culminated in an agreement on 12 December 1950 for a fixed annual sum of 1.3 million DM to be paid by West Berlin. This agreement remained in force until 1954.[47] These payments for net transfers of wastewater were a welcome source of hard currency for East Berlin – and a constant reminder of dependency for the West Berlin utility.

Looking across these experiences in the four service sectors, we can make three general observations. Firstly, the network managers were clearly driven by a strong sense of responsibility to keep the systems working. Notwithstanding the deep political rift between East and West Berlin and distrust between the utilities on either side, the network managers often gave good professional practice preference over ideology when system failure appeared imminent, as the 1953 water supply incident illustrates. As engineers, their problem perceptions were primarily technical, not political. As former colleagues of the same utility company, their loyalties to those they had worked alongside until 1949 often remained strong. Secondly, the very fact that experiences of disconnections differed substantially between the four service sectors suggests that network managers were not following a uniform response pattern determined by their respective occupying powers or city authorities but exercising a modicum of independence in negotiations with their counterparts, at least in crisis situations.

Thirdly, this variation in experience can also be explained in part by the different physical attributes of the sectors and degrees of asymmetry between resource needs and resource availability. In the case of electricity, where West Berlin's dependence on the East was initially very high but where technical options for self-generation could be exploited, conflict escalated to full disconnection. In situations where access to resources was less asymmetrical (e.g. gas) or where there were major physical and technical limitations to redirecting flows (e.g. wastewater) the willingness to reach agreement was greater.

3.2 Longer-term strategies

How did this response modify over the following years as the status of political division became more entrenched and the prospects for reunification more distant? How far did emergency measures to forestall network failure give way to more strategic thinking, and to what end? To answer these questions we compare the responses of network managers in West and East Berlin from the mid-1950s onwards.

West Berlin

As the acute crisis of unpredictable disruption by the Soviet authorities receded in the early 1950s attention in West Berlin turned towards more strategic ways of safeguarding the infrastructure systems. The priority here was, undeniably, to reduce dependency on East Berlin and the Soviet zone:

> "The experience of the blockade made West Berliners insist on complete independence from the East with respect to most of these municipal services."[48]

A repeat of June 1948, when the vulnerability of West Berlin's infrastructure systems had been revealed all too painfully, had to be avoided at all costs. To this end the utilities strove to expand network capacity as fast as possible.

It was no coincidence, therefore, that one of the first acts of city councillor Reuter following the end of the blockade was to call for the reconstruction of Kraftwerk West as a top priority. The speedy delivery of material and equipment and the establishment of substantial coal reserves in West Berlin were designed to act as a deterrent against similar Soviet interventions in the future.[49] By 1952 this flagship power plant had been restored to a capacity of 268 megawatts, already providing the lion's share of the total 382 megawatts at West Berlin's disposal.[50] As the generating capacity of Bewag-West grew, with extensions to other power stations in Moabit, Charlottenburg, Steglitz and Spandau, so did the company's bargaining position vis-à-vis the East. Negotiations for renewed cross-border electricity transfers in the summer of 1953 resulted in a much more advantageous deal for West Berlin.[51] By early 1955, within an extraordinarily short period of time, Bewag-West had become self-sufficient in electricity generation. Not requiring electricity imports from the East any more the transfer agreement was not renewed.

As with electricity, the West Berlin authorities were keen to expand their own gas production and storage capacity. Using funds from the Marshall Plan West Berlin more than doubled its daily production of town gas at its new gasworks in Mariendorf between 1949 and 1954 – from 306,000 m^3 to 700,000 m^3 per day – increasing this further to 1.5 million m^3 by 1960.[52] It also attempted to acquire a long-distance supply of gas from the Ruhr – without success. The third major project was to store huge quantities of gas underground in Spandau. Launched in 1977 and envisaging the storage of ca. 1 billion m^3 of natural gas, this scheme did not come to fruition until 1992 (i.e. after the fall of the Berlin Wall) owing to protracted negotiations with Soviet and West German gas supply companies.[53]

The capacity of West Berlin's water supply network was similarly insufficient to meet demand.[54] West Berlin had relatively limited groundwater resources at its disposal and the network was dependent on a few large waterworks in the North-West of the city. The priority, as with electricity, was to raise supply capacity as quickly as possible. Major investments were made in building a new waterworks at Riemeisterfenn in 1955 and extending the capacity of the waterworks at Beelitzhof in 1953 and, in subsequent years, at the Spandau, Tiefwerder, Jungfernheide, Tegel and Kladow waterworks.[55] A water mains repair programme reduced leakage substantially. The water utility also applied innovative techniques to increase drinking water reserves, notably extensive forms of groundwater enrichment. Already by 1953 dependence on water 'imports' from the East had been reduced significantly and contacts with East Berlin counterparts had become less necessary. Several cross-border water mains were opened merely to keep the pipes clean. By 1978 the supply capacity of West Berlin's waterworks had increased by 227% against the 1949 figure.[56] Despite the rapid growth of water consumption in West Berlin between 1950 and the mid-1970s parallel increases to supply capacity prevented disruption to water services.[57] During an unusually hot summer in 1975 the utility coped without mishap.

Interdependencies between West and East over wastewater were more complex. On the one hand West Berlin disposed of only 10% of its wastewater on its own territory, at the irrigation fields at Karolinenhöhe, making it highly dependent on the surrounding German Democratic Republic (GDR). On the other hand the GDR had a vested interest in avoiding wastewater pollution of lakes and watercourses downstream of West Berlin. On 2 October 1951 the West Berlin Senate, as the city government was now termed, presented an internal report on various options for rendering the wastewater system independent of East Berlin and the GDR.[58] Interestingly, the one chosen was against provisional measures designed to provide immediate relief for the critical disposal situation and in favour of a long-term plan for structural

autonomy. On the basis of this strategy the decision was taken in 1953 to build three completely new sewage treatment plants (STPs) inside West Berlin, at a cost of 87 million DM, of which 50 million DM were to be funded by the European Recovery Program.[59] This scheme, which involved substantial re-routing of wastewater flows within the existing radial system, was implemented with the construction of the STPs Ruhleben (1957-63) and Marienfelde (1968-74). The third planned STP was never built. By 1989, when the Wall fell, only 28.3% of West Berlin's wastewater had to be disposed of, or treated, on East German territory – a major reduction from the 90% figure 40 years previously.[60] Between 1950 and 1990 the West Berlin sewer network was extended in length from 1,414 km to 5,169 km and the number of connected buildings more than doubled.[61] This major programme of infrastructure upgrading and extension, we should note, was not untypical of developments in the Federal Republic at the time. Growing recognition of the environmental cost of economic growth was lending additional weight to strategies of network modernisation. Where West Berlin differed was in the strategic and technical orientation towards greater self-reliance. As with the water, electricty and gas supply systems, the West Berlin wastewater utility invested heavily in new technologies designed to meet the city's peculiar geography of insularity. The two new STPs incorporated special space-saving design features, the stormwater drainage system was expanded, including the construction of eight underground rainwater retention basins, and a novel technique for sludge incineration was introduced in the 1970s to permit sludge treatment within the confines of West Berlin.[62]

These major infrastructure building programmes substantially increased the network capacity of West Berlin. Dependency on the East was sharply reduced and asymmetries of capacity were even reversed in some instances. As a result transfer payments from the West to the East declined significantly and – most important of all – the West Berlin authorities acquired greater control over their infrastructure systems. West Berlin's strategy to maximise

autonomy via major network reconstruction and expansion did come at a price, however. The investment programmes were hugely expensive. The reconstruction of Kraftwerk West alone cost $30 million, the new STP at Ruhleben $12 million.[63] Total investments in the West Berlin wastewater disposal system between 1950 and 1989 amounted to around DM 3,800 million.[64] Richard Merritt estimated in 1968 that the direct and indirect costs for increasing network independence from the East for all infrastructure sectors amounted up until that time to some $250 million.[65] This price tab was picked up not primarily by West Berlin consumers – who paid charges for their municipal services comparable with West German cities – but by the Federal Government, in the form of subsidies, and international funding schemes. In other words the financial costs of political division for the infrastructure systems were internalised by the West German government and Western Allies as an expression of political solidarity with West Berlin. What the political price of West Berlin's increased self-reliance was for Berlin as a whole will be discussed in the subsequent section.

East Berlin

The East Berlin utilities also planned to re-orientate their supply and disposal systems around the particular needs of their own political territory, despite being generally less dependent on the other side than West Berlin.[66] However, the proposals of the infrastructure planners to repair, extend and reorder the technical networks were, for a long time, not heeded. Applications for funding from the state planning system fell on stony ground throughout the 1950s and 60s, despite repeated warnings from those closely involved of the dire consequences of underinvestment for the condition of the physical infrastructure and the quality of municipal services.[67] The high priority accorded to industrialisation and housing construction by the state planning system resulted in meagre funding for technical infrastructures.[68] This hit the water/wastewater sectors particularly hard, reducing supply standards and system reliability. The supply capacity of East Berlin's waterworks fell

significantly between 1949 and 1970, from 715,000 m^3/day to 525,000 m^3/day, partly owing to the contamination of several wells with phenol and coli bacteria.[69] A decision made in 1956 to build a new sewage treatment plant at Falkenberg was not implemented until 1963. In the 1950s, and increasingly in the 1960s, the water networks were subject to technical failures, such as mains bursts, significant drops in water pressure and malfunctions in sewage pumping stations and irrigation farms.[70] As water supply capacity failed to keep pace with growing demand areas were subject to supply cut-offs and rationing. In the summer of 1970, when demand exceeded supply capacity by an estimated 50,000 m^3/day, large parts of the centre of East Berlin went without water.[71] At the same time as West Berlin was investing heavily in upgrading and reordering its technical infrastructure East Berlin's own infrastructure was being starved of funds, causing the city to lose many of the comparative advantages it had possessed in the early 1950s.

Only after the 8th Party Conference of the Socialist Unity Party and the announcement of a major housing programme in 1973 was higher priority given to upgrading the infrastructure systems in East Berlin.[72] For the first time, substantial investments were allocated to improving wastewater treatment, resulting in the completion of the STP at Münchehofe in 1976 and the construction of a new STP at Schönelinde in 1979-87. The sudden willingness to fund the STPs can be explained largely by the fact that the new housing estates were to be sited on wastewater irrigation farms, requiring alternative and – above all – space-saving forms of sewage treatment.[73] Following the modernisation of East Berlin's waterworks water supply capacity in 1980, at 810,000 m^3/day, well surpassed 1949 levels.[74] As an expression of growing recognition by the planning authorities of the importance of technical infrastructure to the city's development, a general plan for the future development of all technical networks (*Generalplan Stadttechnik*) was adopted in 1980.[75] Despite these improvements the repair and upgrading of the technical networks failed to keep pace with the needs of urban expansion and

growing demand.[76] When the Berlin Wall fell in 1989 most networks in East Berlin were in a chronic state of disrepair.

4 New geographies of urban infrastructure

The coping strategies of network managers in West and East Berlin were not geared solely to extending capacity in their respective territories but also, significantly, to rearranging the geographies of their infrastructure systems to their advantage, as far as this was physically, technically and financially possible. In the following section we interpret the empirical findings above to ascertain how spatially cohesive or disruptive infrastructure strategies proved in Berlin following political division. We begin by identifying three dimensions of spatial re-ordering characteristic of the utilities' strategies. We then ask what consequences this had for the territorial integrity of Berlin as a whole.

4.1 Selective territorial cohesion

i. Truncated spaces

The truncation of electricity and water supplies created new infrastructure boundaries at the points of intersection between the two political regimes. Territories which had for decades been interconnected with cables, pipes and ducts transporting electricity, gas, water or wastewater were suddenly separated. Boundaries between the two sectors of the city and the Soviet zone, previously invisible from an infrastructure perspective, suddenly became areas of tension between two opposing regimes. Following the erection of the Berlin Wall in August 1961 the East German authorities were keen to prevent the flow of people, not just natural resources and energy, from East to West. In response to a number of successful escape attempts through the city's sewers, metal barriers were erected to permit the passage of

sewage but not of humans.[77] Along the inner-city border physical connections were closed off, underground barriers erected and residual flows scrutinised to determine transfer payments. Behind the boundary between West and East each political system sought to corral its own infrastructure networks around the territory over which it had control.

ii. Consolidated spaces

This reordering of the technical networks around the new geography of the city was not immediate but developed in intensity during the 40 years of division. West Berlin's electricity supply system, cut off from the national grid and East Berlin, was reoriented around the political-administrative territory of the western sector, generating all its own power by the mid-1950s (see Figure 1). The West Berlin water utility created a completely new West-East axis to its water mains to compensate for the loss of supply from waterworks in East Berlin (see Figure 2).[78] Similarly, the siting of West Berlin's new STPs within the city limits – in Ruhleben and Marienfelde – was designed to redirect wastewater flows within the city, internalising wastewater treatment and minimising dependence on the GDR.[79]

Figure 1: Location of power stations in Berlin

[Insert Figure 1 about here]

Key to power stations (with today's electricity generating capacity): 1: Reuter West (1987-) 600 MW, 2: Lichterfelde (1972-) 450 MW, 3: Charlottenburg (1900-) 385 MW, 4: Mitte (1964-) 380 MW, 5: Wilmersdorf (1911-) 280 MW, 6. Reuter (1928-) 232 MW, 7: Moabit (1899-) 151 MW, 8: Klingenberg (1925-) 180 MW, 9: Lichtenberg (1972-) 72 MW, 10: Steglitz (1931-2000), 11: Oberhavel (1961-2000), 12: Rudow (1963-2003)

Source: Tepasse, *Stadttechnik im Städtebau Berlins*, 208

Figure 2: West Berlin's water mains network

[Insert Figure 2 about here]

Source: Bärthel, *Wasser für Berlin*, 284

iii. By-passed spaces

East Berlin and the GDR, confronted with a significant 'hole' in their networks left by West Berlin, responded by reordering their principal electricity cables, gas pipelines and water mains so that they circumvented the western sector and targeted the new housing settlements on the edge of East Berlin, as clearly demonstrated in the *Generalplan Stadttechnik* of 1980 (see Figure 3).[80] The siting of new STPs in the 1970s in the new development zones to the East of the city is also indicative of spatial reorientation away from the old centre. In an effort to disentangle the sewer network close to the border with West Berlin the East Berlin authorities even built a number of so-called "border pumping stations" to redirect wastewater flows away from the West, primarily as a means of avoiding transfer payments.[81] Besides this shift eastwards within the city, the East Berlin utilities drew increasingly on resources from the GDR at large. In the case of gas, East Berlin had been badly affected by the complete stoppage of gas deliveries from the West during the blockade (see above). Following unsuccessful attempts to meet growing demand by producing gas from coal in municipal gasworks, the strategy shifted to increasing the delivery of natural gas supplied long-distance from the Soviet Union.[82] In the case of electricity, East Berlin also relied increasingly on external sources, in the form of power supplied from the Lausitz and Bitterfeld coalfields in the GDR.[83]

Figure 3: East Berlin's water mains network

[Insert Figure 3 about here]

Source: Bärthel, *Wasser für Berlin*, 228

4.2 The price of territorial reorientiation

These strategies of infrastructural separation and reorientation were promoted on both sides of the divide as a means of protecting their own territorial integrity. The notion of infrastructure as a force for spatial cohesion and urban development was retained, but the spatial terms of reference were the newly truncated territorial units, not the city as a whole. Infrastructure development was used, as we have seen, as an instrument of political and economic security as well as service provision. The idea that the reordered geography of Berlin's infrastructure systems could have long-term negative impacts on the future development of the city as a whole was given relatively little consideration at the time, as the American political scientist Richard Merritt discovered in interviews conducted with network managers during the 1960s.[84]

Merritt himself was concerned about the irreversibility of the changes to Berlin's infrastructure systems and the risks this posed for the potential reunification of the two half-cities at some time in the future:

> "The infrastructural aspects of a political community […] exhibit remarkable durability and tenacity in resisting change. The very tenacity of the infrastructure, however, suggests that, once change is initiated, its reversal will be very difficult. The developments [in post-war Berlin] thus portend an ever growing divergence of West and East Berlin, respectively, from the old centre of Greater Berlin, and increased solidification of each around its new core area."[85]

Infrastructure planners did share these concerns and, especially in the early years of division, gave some consideration to possible reunification.[86] However, the risk of establishing structures which might be difficult to reorder following any reunification was generally deemed less significant at the time than the danger of not being able to safeguard essential

services. Minimising dependence on the other side of the city was accorded a much higher priority than keeping the reunification option open. Merritt criticised West Berlin's network managers for paying lip service to reunification while "enhancing the city's invulnerability to threats to its independence".[87] He charged both sides with "pass[ing] up chances for fruitful cooperation – primarily for the sake of increasing the viability of the utilities in their own sectors".[88]

Merritt painted a picture of divergent pathways between East and West driving a rift between the two sets of infrastructure systems which reduced the prospects for their reunification. He was certainly correct in arguing how the two sets of infrastructure systems became increasingly self-dependent during the decades of political division. He was also right in demonstrating that this divergence was not limited to the technical/physical dimensions of infrastructure systems but also to their organisational structures and institutional arrangements. The West Berlin utilities were responsible to the city government but had considerable autonomy over investment plans and operative management. In addition, as we have seen, they received significant funding from the city, the Federal government and the international donor community. By contrast, the East Berlin utilities were institutionally weak and continuously under-funded. They came under the powerful influence first of the Soviet authorities and subsequently of the state planning bodies and suffered at least until the 1970s from the low priority accorded to infrastructure refurbishment in the state planning system.

Yet the thesis of divergent, even irreconcilable, pathways is only partly accurate. If we look closer at the strategies pursued by network managers in West and East and at the underlying rationales for their actions we can detect one powerful parallel. On both sides of the divide the network managers were intent on repairing, modernising and expanding their technical networks to meet rising demand. Their prime concern was to ensure maximum connection to municipal services, adequate supplies of electricity, gas and water for all consumers at all

times and failure-free operation of the networks. Network managers in West and East Berlin followed the same supply-oriented logic of infrastructure management which their predecessors had pursued since the late 19th century. The results may have been very different, but this can largely be attributed to asymmetries in the availability of financial resources. The rationales motivating the network managers and guiding their strategies were, essentially, the same.

The experience of reunifying the infrastructure systems of West and East Berlin after 1990 would also suggest that the legacy of division was not as deep as it appeared at the time.[89] Technically, the networks were reconnected and barriers removed within weeks of the fall of the Berlin Wall. Organisationally, the amalgamation of the utility companies from West and East was complete within a few years. Financially, huge investment programmes during the 1990s permitted the rapid modernisation and expansion of the East Berlin plant and networks. Here, again, the supply-oriented logic proved an important uniting factor. Whatever the difficulties encountered in the reunification process, the idea of bringing East Berlin's infrastructures up to the standards enjoyed by West Berlin was a vision which all could share. The negative legacy which the period of division did leave was, ironically, a problem of over-capacity. Having struggled to maintain services in two truncated territorial units, the strategy of both sides to build up their own, largely self-dependent infrastructure systems meant that, when they were rejoined in 1990, there quickly proved to be too many power stations, sewage treatment plants, waterworks and gasworks. As the population of the reunited Berlin has failed to grow according to expectations and consumption of water, in particular, has dropped sharply, Berlin's utility managers today are confronted with the unusual phenomenon of under-utilised networks and surplus plant.

5. Conclusions

What conclusions can we draw from our analysis of the division of Berlin's infrastructure systems following the blockade of 1948/49? One set of observations relates to the nature of the crisis and the interdependence between the city and its infrastructure which it revealed. The network disruption which Berlin's infrastructure systems suffered in the late 1940s and early 1950s was not the result of forces endogenous to them but of the geopolitical conflict of the Cold War, with Berlin as the principal pawn. Technical networks played a central role in this proxy conflict. Severing West Berlin's electricity supply was one of the first acts of the blockade, deliberately chosen to destabilise a city largely dependent on outside supplies. Subsequently, municipal services for gas, water and wastewater on both sides of the city were seriously disrupted by physical disconnections, political disputes and tenuous transfer agreements. Beyond the flows of energy and water the division of the city stopped or curtailed other flows of central importance to their functioning, most notably of people, equipment and information. The infrastructure systems became not merely targets but also tools of political division enrolled in the protection of one political regime against the other, creating structures of supply and disposal crucial to the survival of each part of the city. New geographies of infrastructure provision emerged to advance the territorial cohesion of each side, characterised by the spatial re-ordering of the technical networks and – in West Berlin's case – huge financial support from the West.

A second set of conclusions addresses the responses of the network managers to this crisis and the security concerns which these responses reveal. We have observed how, during the early period of the blockade and political division, the prime concern of the network managers, above all in West Berlin, was to maintain essential services in the face of interventions and reprisals from the other side. Emergency measures were targeted at ensuring the provision of basic – if heavily restricted – supplies of electricity, gas and water. The extraordinary degree

to which they succeeded in keeping the systems going in the face of frequent imminent collapse makes this a remarkable story of infrastructure resilience.

In the longer term the experience of the blockade and the extreme dependence on external forces which it highlighted prompted West Berlin's authorities to seek to maximise self-dependence for all municipal services. The response shifted rapidly from stop-gap measures to network modification. This strategy gradually came to be mirrored in East Berlin, but only when sufficient financial resources become available from the 1970s onwards. Restructuring the technical networks to reduce vulnerability and creating sufficient reserves to withstand external intervention became the top priority for both sides. This strategy took clear precedence over concerns at the negative consequences which restructuring might have on any future reunification of the city and its infrastructure systems.

In terms of the long-term legacy of division to Berlin's infrastructure systems, experience since reunification in 1990 suggests the rift did not run as deep as some commentators feared at the time. The traditional, supply-oriented logic of infrastructure management persisted on both sides of the city, even though financial and political constraints in East Berlin did not allow it to bear fruit until the 1970s, and was instrumental in easing the process of reuniting the utility companies after 1990. In retrospect, we can also see that the physical and technical reordering of the infrastructure systems during the decades of division, although radical and unconventional, did not prevent subsequent reintegration in the 1990s. The changes to Berlin's infrastructure systems during the 40 years of division constituted an adaptation of existing systems to accommodate new geopolitical realities, not a complete transformation. The principal negative legacy of division proved to be the infrastructural over-capacities generated for the reunited city, the product of the strategy on both sides of the divide to maximise capacity for their own territory.

NOTES

[1] Cited in Johann Friedrich Geist and Klaus Kürvers, *Das Berliner Mietshaus* (München: Prestel-Verlag, 1989), 243. Cf. Ernst Randzio, *Unterirdischer Städtebau* (Bremen-Horn: Walter Dorn Verlag, 1951).

[2] For details of the start of the Berlin blockade, see Senat von Berlin, *Berlin. Quellen und Dokumente 1945-1951* (Berlin: Heinz Spitzing Verlag, 1964); Büro für Gesamtberliner Fragen, *Berliner Schicksal 1945-1952*, (Berlin: Büro für Gesamtberliner Fragen, 1952); Dietrich Storbeck, *Berlin – Bestand und Möglichkeiten. Die strukturelle Beharrung und Gemeinsamkeit unter der politischen Spaltung*. Dortmunder Schriften zur Sozialforschung Bd.27. (Köln / Opladen: Westdeutscher Verlag, 1964); Richard L. Merritt, "Political Division and Municipal Services in Postwar Berlin." in *Public Policy* Vol.17, eds. John D. Montgomery and Albert O. Hirschman (Cambridge, Mass.: Harvard University Press, 1968), 165-198; Richard L. Merritt, (1986): "Postwar Berlin: Divided City." in *Berlin Between Two Worlds*, eds. Ronald A. Francisco and Richard L. Merritt (Boulder / London: Westview Press, 1986), 153-175.

[3] Summerton, *Changing Large Technical Systems*, 1. On the development and path dependency of urban infrastructure systems, see the classic socio-technical and historical studies by Joel Tarr and G. Dupuy, *Technology and the Rise of the Networked City in Europe and North America* (Philadelphia: Temple University Press, 1988); Thomas Hughes, *Networks of Power: Electrification in Western Society 1880-1930* (Baltimore: John Hopkins University Press, 1983); Thomas Hughes, "The Evolution of Large Technological Systems," in *The Social Construction of Technological Systems*, eds. W.E. Bijker, T.P. Hughes and T. Pinch (Cambridge: MIT Press, 1987); Olivier Coutard, ed., *The Governance of Large Technical Systems* (London: Routledge, 1999); Anique Hommels, "Studying Obduracy in the City: Toward a Productive Fusion between Technology Studies and Urban Studies." *Science, Technology, & Human Values* 30/3 (2005): 323-351.

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[5] Jane Summerton, ed., *Changing Large Technical Systems* (Colorado: Westview Press, 1994), 2.

[6] Hughes, "The Evolution of Large Technological Systems".

[7] On the relationship between technical infrastructure systems and urban development, see in particular the special issues of the *Journal of Urban History* in 1979 (ed. Joel Tarr), in 1987 (eds. Mark Rose and Joel Tarr) and in 2004 (eds. Mark Rose and Joel Tarr); Joel Tarr, "The Metabolism of the Industrial City: the Case of Pittsburgh," *Journal of Urban History* 28 (2002): 511-545; Martin Melosi, *The Sanitary City: Urban Infrastructure in America from Colonial Times to the Present* (Baltimore: MD, 2000); Martin Melosi, *Effluent America: Cities, Industry, Energy, and the Environment* (Pittsburgh: PA, 2001); Stephen Graham and Simon Marvin, *Splintering Urbanism. Networked Infrastructures, Technological Mobilities and the Urban Condition* (London / New York: Routledge, 2001); Dieter Schott, *Die Venetzung der Stadt. Kommunale Energiepolitik, öffentlicher Nahverkehr und die 'Produktion' der modernen Stadt. Darmstadt – Mannheim – Mainz 1880-1918* (Darmstadt, 1999). On the relationship between urban and infrastructure planning in Berlin see Heinrich Tepasse, *Stadttechnik im Städtebau Berlins. 20. Jahrhundert* (Berlin: Gebr. Mann Verlag, 2006) and Heinrich Tepasse, *Stadttechnik im Städtebau Berlins. 1945-1999* (Berlin: Gebr. Mann Verlag, 2001).

[8] Graham and Marvin, *Splintering Urbanism*, 8.

[9] Michael Stoll, "Verknüpfung geteilter Netze," *Der Architekt* 4 (1995): 240.

[10] See especially Merritt "Postwar Berlin", 15ff; Michael D, Haydock, *City under Siege: The Berlin Blockade and Airlift, 1948-1949* (Brassey's, 1998); Roger G. Miller, *To Save a City: The Berlin Airlift, 1948-1949* (Texas A&M University Press, 2000); Wolfgang Ribbe, "Berlin zwischen Ost und West." in *Geschichte Berlins. Zweiter Band. Von der Märzrevolution bis zur Gegenwart* (München: C.H. Beck, 1987), 1061-1066. On the reconstruction of post-war German cities see Jeffry M. Diefendorf, *In the Wake of War: The Reconstruction of German Cities after World War II* (New York / Oxford: Oxford University Press, 1993) and Jeffry M. Diefendorf, ed., *American Policy and the Reconstruction of West Germany, 1945-1955* (Cambridge: Cambridge University Press, 2004).

[11] Tepasse, *Stadttechnik im Städtebau Berlin. 20. Jahrhundert,* 111.

[12] Richard L. Merritt, "Infrastructural Changes in Berlin." *Annals of the Association of American Geographers* 63/1 (1973): 60.

[13] Wolfgang Brocke and Liselotte Brüss, "Die Berliner Energieversorgung." in *Die unzerstörbare Stadt. Die raumpolitische Lage und Bedeutung Berlins*, ed. Institut für Raumforschung (Köln / Berlin: Carl Heymanns Verlag, 1953), 111-118, especially 113.

[14] Graham and Marvin, *Splintering Urbanism*, 46; cf. Hughes, *Networks of Power*, 175-200.

[15] Merritt, "Political Division", 168.

[16] On the limited wartime damage to infrastructure in other German cities, see Diefendorf, *In the Wake of War*, 19-20.

[17] Brocke and Brüss, "Die Berliner Energieversorgung", 113; Büro für Gesamtberliner Fragen, *Berliner Schicksal*, 254.

[18] Bewag (ed.), *Strom für Berlin. Von der Spaltung zur Wiedervereinigung*. Berliner Kraft und Licht(Bewag)-Aktiengesellschaft (Berlin: Bewag, 1991), 3.

[19] Brocke and Brüss, "Die Berliner Energieversorgung", 113; Merritt "Postwar Berlin", 159.

[20] Merritt, "Political Division", 170.

[21] Senat von Berlin, *Berlin. Quellen und Dokumente*, 736.

[22] Undated, cited in Senat von Berlin, *Berlin. Quellen und Dokumente*, 1482.

[23] Berliner Gaswerke, *100 Jahre Berliner Städtische Gaswerke* (Berlin: GASAG, 1947), 22-23.

[24] Tepasse, *Stadttechnik im Städtebau Berlin. 20. Jahrhundert,* 187.

[25] Tepasse, *Stadttechnik im Städtebau Berlins. 20. Jahrhundert*, 111.

[26] Tepasse, *Stadttechnik im Städtebau Berlin. 20. Jahrhundert,* 187.

[27] Tepasse, *Stadttechnik im Städtebau Berlin, 20. Jahrhundert,* 187.

[28] Büro für Gesamtberliner Fragen, *Berliner Schicksal*, 260.

[29] Hilmar Bärthel, *Wasser für Berlin: Die Geschichte der Wasserversorgung* (Berlin: Verlag für Bauwesen, 1997), 188-189; Tepasse, *Stadttechnik im Städtebau Berlins. 20. Jahrhundert*, 99.

[30] Senat von Berlin, *Berlin. Quellen und Dokumente*, 1459.

[31] Hilmar Bärthel, *Geklärt! 125 Jahre Berliner Stadtentwässerung* (Berlin: Verlag Bauwesen, 2003), 168.

[32] Knut Möhring, *Das Berliner Abwassernetz und die Wiedervereinigung der Stadt. Sonderdruck aus Steinzeug Information* (Berlin: Berliner Wasserbetriebe, 1991), 7.

[33] Bärthel, *Geklärt!*, 203. Merritt, "Political Division", 188, cites an even higher figure of 98%.

[34] On the following, Merritt, "Political Division", 172-177.

[35] Büro für Gesamtberliner Fragen, *Berliner Schicksal*, 259.

[36] Senat von Berlin, *Berlin. Quellen und Dokumente*; Büro für Gesamtberliner Fragen, *Berliner Schicksal*; Merritt, "Political Division"; Merritt, "Postwar Berlin"; Bärthel, *Wasser für Berlin*, 194ff.

[37] Merritt, "Political Division", 176-177, 186-187.

[38] Tepasse, *Stadttechnik im Städtebau Berlin. 20. Jahrhundert,* 187.

[39] Bärthel, *Wasser für Berlin*, 236-237.

[40] Merritt, "Political Division", 190.

[41] Merritt, "Political Division", 194-195, footnote 60.

[42] Merritt, "Political Division", 178.

[43] Merritt, "Political Division", 182.

[44] Brocke and Brüss, "Die Berliner Energieversorgung", 118.

[45] Tepasse, *Stadttechnik im Städtebau Berlins. 20. Jahrhundert*, 99; Bärthel, *Wasser für Berlin*, 195.

[46] Merritt, "Political Division", 187.

[47] Bärthel, *Geklärt!*, 174; Tepasse, *Stadttechnik im Städtebau Berlins. 20. Jahrhundert*, 194.

[48] Merritt, "Postwar Berlin", 159.

[49] Senat von Berlin, *Berlin. Quellen und Dokumente*, 1554.

[50] Brocke and Brüss, "Die Berliner Energieversorgung", 114; Tepasse, *Stadttechnik im Städtebau Berlin. 20. Jahrhundert,* 204.

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[55] Bärthel, *Wasser für Berlin*, 272ff.

[56] Bärthel, *Wasser für Berlin*, 278-279.

[57] Tepasse, *Stadttechnik im Städtebau Berlins. 20. Jahrhundert*, 202.

[58] Bärthel, *Geklärt!*; Merritt, "Political Division".

[59] Tepasse, *Stadttechnik im Städtebau Berlins. 20. Jahrhundert*, 195.

[60] Tessendorff, "Berliner Wasserbetriebe", 555; Möhring, *Das Berliner Abwassernetz*, 5.

[61] Bärthel, *Geklärt!*, 231.

[62] Tessendorff, "Berliner Wasserbetriebe", 558-559.

[63] Merritt, "Political Division", 191.
[64] Bärthel, *Geklärt!*, 232.
[65] Merritt, "Political Division", 191.
[66] Bärthel, *Wasser für Berlin*, 200.
[67] Bärthel, *Wasser für Berlin*, 205.
[68] Möhring, *Das Berliner Abwassernetz*, 5.
[69] Bärthel, *Wasser für Berlin*, 233; Tepasse, *Stadttechnik im Städtebau Berlins. 20. Jahrhundert*, 202.
[70] Bärthel, *Wasser für Berlin*, 205; Bärthel, *Geklärt!*, 179.
[71] Bärthel, *Wasser für Berlin*, 204-205.
[72] Bärthel, *Geklärt!*, 190ff.
[73] Tepasse, *Stadttechnik im Städtebau Berlins. 20. Jahrhundert*, 198-199.
[74] Bärthel, *Wasser für Berlin*, 133.
[75] Bärthel, *Wasser für Berlin*, 212.
[76] Bärthel, *Wasser für Berlin*, 226; Bärthel, *Geklärt!*, 201-202.
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[78] Bärthel, *Wasser für Berlin*, 238-239.
[79] Bärthel, *Geklärt!*, 215ff.
[80] Stoll, "Verknüpfung geteilter Netze", 241; Bärthel, *Wasser für Berlin*, 212.
[81] Möhring, *Das Berliner Abwassernetz*, 7.
[82] Tepasse, *Stadttechnik im Städtebau Berlin. 20. Jahrhundert,* 188.
[83] Tepasse, *Stadttechnik im Städtebau Berlin. 20. Jahrhundert,* 207.
[84] Merritt, "Political Division"; Merritt, "Postwar Berlin".
[85] Merritt, "Postwar Berlin", 163.
[86] Bärthel, *Wasser für Berlin*, 281-282.
[87] Merritt, "Political Division", 193.
[88] Merritt, "Political Division", 191.
[89] On Berlin's infrastructure development following reunification in 1990 see Timothy Moss, "Utilities, Land-use Change and Urban Development: Brownfield sites as "Cold-spots" of Infrastructure Networks in Berlin." *Environment and Planning A* 35 (2003): 511-529; Timothy Moss, "Unearthing water flows, uncovering social relations: introducing new waste water technologies in Berlin." *Journal of Urban Technology* 7/1 (2000): 63-84; Timothy Moss, "Institutional Restructuring, Entrenched Infrastructures and the Dilemma of Over-capacity." In *Sustainable Consumption: the Implications of Changing Infrastructures of Provision*, eds. Dale Southerton, Heather Chappells and Bas van Vliet (London: Edward Elgar, 2004), 97-112.